

an ever-increasing knowledge of all aspects of insect-borne diseases has provided the foundations essential to the success of applied control measures. Seemingly the major limiting factor in the achievement of unprecedented, constructive victories is the modest economic burden that would be temporarily imposed.

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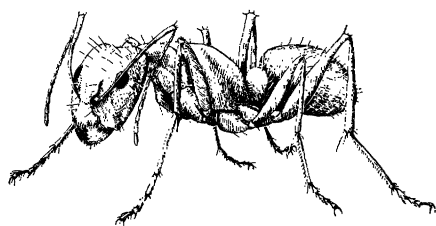
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## Insects and Helminths

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Many species of the helminths, or parasitic worms, of livestock and poultry can pass through certain of their early stages only within the body of an insect. These species are transmitted, in the true sense, by insects. Beetle mites or grass mites similarly transmit others. One species is transmitted by a tick as well as by insects. These particular species of worms are obligatory parasites of insects, or their allies, just as truly as they are obligatory parasites of farm animals or birds. For their continued existence and propagation, for their survival as species, they depend equally upon insect and upon avian or mammalian hosts.

The life cycle of a helminth of one of these species, like the life cycle of all other parasitic helminths, is initiated by the eggs or microscopic larvae produced by the mature female or hermaphroditic individual. But depending on its specific identity, its eggs or larvae are infectious only to an insect or a mite or perhaps a tick. If ingested by a suitable insect, for example, each egg or larva gives rise to a more advanced developmental stage of the parasite, which takes up its abode in some part of the insect's body. There, however, the development of the worm stops at a stage far short of reproductive maturity. Unless this arrested-developmental stage gains access to the body of a suitable vertebrate animal, the life cycle of the parasite cannot be completed. Obviously, therefore, any step that can be taken to destroy infected insects will aid in preventing the infection of livestock and poultry with worms that have this type of life cycle. The world-wide extermination of the insect vectors, were this possible, would



*Camponotus castaneus*, a common ant.

result automatically in the extermination of a goodly proportion of the species of worms that now afflict man and his domestic animals and many others that live in wild animals and birds.

Worms that are obliged to undergo development in two or more hosts are called heteroxenous parasites. The hosts in which they can reach reproductive maturity are called final or definitive hosts. Hosts in which their larval stages must develop before the parasites can take up life in a final host are called intermediate hosts.

Some instances of the transmission of parasitic worms by insects were discovered before it was learned that insects are also vectors of some of the most devastating protozoal and infectious diseases known to medical and veterinary science. Some years before the transmission of malaria or yellow fever by mosquitoes or of southern cattle fever by ticks was discovered, it had been demonstrated that the larvae of a nematode worm, *Wuchereria bancrofti*, which causes human filariasis, could be sucked up by a feeding mosquito and would undergo developmental transformation in its body.

Very few kinds of parasitic worms can multiply—that is, reproduce through successive generations—entirely within the body of the animal in which they mature. The eggs or larvae of nearly all species must leave the host's body to perpetuate the parasite.

The eggs or larvae of worms that live in the digestive tract or in an organ or system (such as the liver or respiratory system) that communicates with the digestive tract or in the urinary system ordinarily pass from the host with its feces or urine. The presence of the progeny of the worms in those substances, which in natural circumstances are deposited by livestock and poultry on the ground, leads to their ingestion by various kinds of invertebrate and vertebrate animals. Although the insects and their close relatives are perhaps the most ubiquitous of the invertebrates and are of outstanding importance as vectors of

parasitic worms, the eggs and larvae of some of the heteroxenous worms of farm animals and birds are not infectious to them. Other arthropods, snails, slugs, earthworms, or other animals serve as intermediate hosts in those instances.

Some of the insect vectors of worms that produce eggs, which leave the definitive host's body in the manner described, habitually feed upon the excrement of higher animals. In the process they ingest the worm eggs and thus become infected. Others are not susceptible as adults to infection or at least do not become infected. They habitually deposit their eggs in excrement or in materials contaminated by it. The larvae that hatch from their eggs ingest the worm eggs and are susceptible to infection by them. In other instances the insects involved cannot be classified as coprophagous—dung eating—nor do they customarily or preferentially breed in manure. But natural forces continually scatter worm eggs into their habitats. They ingest quite incidentally the worm eggs that contaminate their normal food supply.

Some of the vectors are themselves ectoparasites of farm animals. They normally feed upon the cellular debris or detritus on the skin of their hosts. They take in worm eggs when the skin is contaminated with fecal matter or crushed parts of worms.

Some of the heteroxenous worms live in situations, such as the circulatory system or subcutaneous tissues, that have no connection with the external body openings of the host. They include several species of viviparous roundworms, or Nematoda, which eject the larvae they produce into their host's blood, or lymph, or dermal skin layers. There the larvae remain, ultimately to perish unless they are ingested by a biting or bloodsucking insect.

Not only do the habits, habitats, and structural modifications of the various insects and certain of their close relatives lead these arthropods to ingest the microscopic progeny of parasitic worms of many kinds. The insects like-

wise afford an almost ideal means of transport of the infectious stages of the worms back to the definitive hosts, livestock or poultry. Many of them form part of the normal diet of birds. In grazing, swine, sheep, cattle, and horses cannot avoid taking in beetles, mites, and similar insects along with the herbage they consume. A dog or cat suffering from infestation by fleas or lice, bites and licks at the noxious creatures and swallows some of them. A female mosquito must have a blood meal before it can lay fertile eggs and a further blood meal between every two batches of eggs it lays. If, between meals, infectious worm larvae have developed in its body, it injects these into the blood of the next animal it bites.

Many adaptations exist among insects, parasitic worms, and the definitive hosts of the worms. Farmers can take advantage of some of these adaptations to protect livestock and poultry against the inroads of insect-borne worm infections.

INSECTS FREQUENT FECAL and related waste materials because those substances are essential for their growth and development or because they contain something that attracts insects—a bright or moving object, for example. Segments of tapeworms, because of their bright color or ability to move, readily attract insects and mites and often are eaten by them.

Insect-borne worms of livestock and poultry include representatives of all four of the major groups of helminths: Roundworms (Nematoda), tapeworms (Cestoda), thorny-headed worms (Acanthocephala), and flukes (Trematoda). Those that are transmitted by habitual or accidental dung feeders inhabit the digestive tract of the definitive host or organs that communicate with this tract; as has been noted, the eggs or larvae of worms living in these situations occur in the host's feces.

Various species of tumble bugs and dung beetles are intermediate hosts for worms occurring in swine, sheep, cattle, poultry, cats, and dogs. Two stom-

ach worms, *Ascarops strongylina* and *Physocephalus sexalatus*, of swine, and the gullet worm, *Gongylonema pulchrum*, which occurs in swine, sheep and cattle, utilize such coprophagous beetles as *Copris*, *Aphodius*, *Passalurus*, *Onthophagus*, *Scarabaeus*, *Gymnopleurus*, *Ataenius*, *Canthon*, *Phanaeus*, and *Geotrupes* as intermediate hosts. The German cockroach also serves as an intermediate host of the gullet worm. The eggs ingested by the insects contain well-developed embryos at the time of oviposition. On hatching in the insect's gut, the larvae first enter the abdominal cavity of the intermediate host and finally come to rest in the walls of the Malpighian tubules or musculature, where they become encysted. Completely formed cysts are usually found free in the abdominal part of the body cavity. The larvae become infective in the intermediate host in a month or so.

The larvae of the esophageal worm, *Spirocercus lupi*, of the dog develop to the infective stage in the beetle, *Scarabaeus sacer*, and other beetles. The infective larvae become encysted in these insects, chiefly on the tracheal tubes. If such beetles are swallowed by an unsuitable host, such as a frog, snake, bird, or a small mammal, the larval worms become encysted again in the esophagus, mesentery, or other organs of these animals. This phenomenon is also known to occur in the case of the swine stomach worm, *Physocephalus sexalatus*, the larvae of which have been found naturally reencysted in the wall of the digestive tract of such birds as the loggerhead shrike, screech owl, and red-tailed hawk in southern Georgia and northern Florida. Reencystment of the larvae was found in experiments to occur in many different animals, including birds, mammals, and reptiles, to which beetles containing infective larvae were fed.

One of the commonest species of tapeworms, *Hymenolepis carioca*, found in the domestic fowl, is transmitted by beetles (*Aphodius*, *Choeridium*, *Hister*, and maybe *Anisotarsus*).

Another species of tapeworm, *Hymenolepis cantaniana*, found in chickens, turkeys, and quail of the Eastern States, develops in the beetles *Ataenius* and *Choeridium*. Its development in its intermediate host is unusual. The larva elongates to form a somewhat branched myceliumlike structure; buds along the branches develop into the cysticeroids, or small larval forms, which contain the tapeworm heads. Tapeworms belonging to the genera *Joyeuxiella* and *Diplopylidium*, which are closely related to *Dipylidium*, occur in cats and apparently develop in dung beetles and related insects. It takes about 3 weeks to 2 months, depending on temperature, for the cysticeroids to develop within the insect host. Completely developed cysts are found in its body cavity. The tapeworm *Metrolia-sthes lucida*, commonly found in the small intestine of the domestic and wild turkey, is reported to have the grasshoppers *Melanoplus* sp., *Chorthippus longicornis*, and *Paroxya clavuliger* as intermediate hosts. Guinea fowls are also susceptible to infection with this tapeworm.

Dermestid beetles, darkling beetles, fungus beetles, and other groups of beetles and several species of grasshoppers have been infected experimentally, or found to be infected naturally with the larvae of the gizzard worm of poultry, *Cheilosporura hamulosa*.

Small numbers of these worms in the gizzard do not produce any serious results. In heavy infections, the lining of the gizzard may show ulcerations, which may also involve the musculature. Soft nodules enclosing the parasites are often found in the muscular portions, especially in the thinner parts of the gizzard. In the intermediate host, the infective larva of the gizzard worm is found encysted in the musculature of the body wall, where it is found to be tightly coiled. The infective stage is reached in about 19 days.

Darkling beetles (*Alphitobius*, *Gonocephalum*, and *Ammophorus*), the ring-legged earwig, and the hide beetle

have been reported as being infected with the third-stage larvae of *Subulura brumpti*, the cecal worm of poultry. The final host becomes infected through the ingestion of the infected intermediate host and the larvae pass to the cecum, the blind gut. Many species of darkling beetles and ground beetles have been incriminated as intermediate hosts of *Raillietina cesticiillus*, the broad-headed tapeworm of poultry and of another poultry tapeworm, *Choanotaenia infundibulum*. The latter also develops in the red-legged grasshopper and in the house fly. The chief effect of this tapeworm, even in heavy infestations, is to retard the growth rate of its host.

The Surinam roach, and possibly other species of cockroaches, is an intermediate host for three nematodes of poultry, namely, the eyeworms, *Oxy-spirura masoni* and *O. parvovum*, and the proventricular worm, *Seurocyrnea colini*, of the turkey and bobwhite quail. Infections with the eyeworms result in a marked irritation, which interferes seriously with vision. It often is accompanied by continual winking as if to dislodge a foreign body. The nictitating membrane of the eye becomes inflamed and appears as a puffy elevation. Heavy infestations may cause blindness. The German cockroach has been shown in experiments to serve as an intermediate host for *Seurocyrnea colini*. This cockroach, the red-legged grasshopper, and the differential grasshopper have been reported to be suitable intermediate hosts for the globular stomach worm, *Tetrameres americana*, of chickens, bobwhite quail, and turkeys. After the eggs are ingested by the intermediate hosts, the larvae of this stomach worm pass into the body cavity and become quite active for the first 10 days after infection. They then penetrate the muscles and become loosely encysted. In about 42 days, or possibly sooner, the infective larvae have completed their development. The vitality of grasshoppers is greatly reduced by infections with this parasite. Some die and some

become inactive and an easy prey to birds. The infection is transmitted to the bird through the ingestion of the infected intermediate host. Serious infections with these species of stomach worms have not been noted in domestic birds in the United States.

Several species of ants, of the genera *Tetramorium* and *Pheidole*, are naturally infected with cysticercoids of two closely related poultry tapeworms, *Railletina tetragona* and *R. echinobothrida*. Experimental attempts to infect ants of these and other genera by feeding to them eggs of these tapeworms resulted in failure, but naturally infected ants were fed to chickens and infections resulted.

Quail are said to be seriously parasitized by *R. tetragona* and death losses have been attributed to this tapeworm, but its pathogenicity has not been experimentally verified.

However, *R. echinobothrida* is definitely known to be one of the most injurious tapeworm parasites of poultry. It causes the formation of tuberclelike nodules on the intestinal wall, which closely resemble the nodules of tuberculosis. The absence of the nodules in the liver, spleen, and other internal organs and the presence of tapeworms in the small intestine warrant the diagnosis of this infection and exclude tuberculosis.

Biting lice are minor vectors of worm parasites. The only known instance involves the dog biting louse, which is reported to be an intermediate host of the double-pored tapeworm, *Dipylidium caninum*, of the dog and cat. Because this louse normally feeds on particles of dried skin of its host, it can hardly be classified as a coprophagous insect. It is presumed that the skin of the dog and cat, especially in the perianal region, becomes contaminated with eggs of the tapeworm, which are more or less incidentally eaten by the louse.

Beetle mites, also known as oribatid or galumnid mites, serve as vectors of the broad tapeworm, *Moniezia expansa*, of cattle, sheep, and goats.

After being expelled with the host's feces, the tapeworm eggs must become fairly dry and well anchored before the mites can ingest them. The mites usually do not eat the entire egg. They make a hole in its shell and ingest its contents. This tapeworm adversely affects the growth of infected lambs. Several investigators have reported that *M. expansa* produced scouring in range lambs. In experiments, however, infected lambs have not shown scouring.

The life history of *M. expansa*, which had defied investigators for many years, was solved in 1937. Since then it has been shown that oribatid mites also are the vectors of several other anoplocephalid tapeworms of domestic animals. They transmit *Citotœnia ctenoides* and *C. denticulata* of rabbits; *Anoplocephala perfoliata*, *A. magna*, and *Paranoplocephala mamillana* of horses; and *Moniezia benedini* and *Thysaniezia giardi* of ruminants.

Beetle mites are most apt to be abundant in moist, shady places. They are found in pastures both winter and summer, but they increase markedly in numbers with the new growth in spring. The mites are generally distributed throughout the world.

THE NUMBER of groups of insects in which infection takes place in the larval or immature stage is small, compared to those that acquire the infection in the adult stage. In some instances the mouth parts of the adult insect are of the sucking type so that solid materials cannot be ingested, or its feeding habits are such that it does not come in contact with materials containing the worm eggs and larvae. The larval insects, however, hatch out in such material, and their mouth parts are adapted for its ingestion.

The house fly and the stable fly breed abundantly in horse manure. Their maggots migrate extensively throughout manure piles and feed promiscuously on the materials found therein. The maggots of the house fly are the

intermediate hosts for two nematodes (roundworms) commonly found in the stomachs of horses—*Habronema muscae* and *Drashia megastoma*. Those of the stable fly are suitable hosts for the development of a third horse-stomach worm, *Habronema majus*.

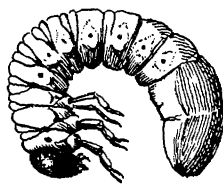
The nematode larvae undergo several molts within the body of the fly maggot and reach the infective stage about the time the fly hatches. The adult fly harbors the infective larvae free in the body cavity, but some of the larvae may migrate into the mouth parts of the fly. The horse presumably becomes infected when the flies in feeding deposit worm larvae on its lips or by ingesting flies which get into its food or water.

The thorny-headed worm is a rather common parasite of swine, particularly in the South. Characteristic nodules form at the sites of attachment of the worms to the wall of the small intestine. Sometimes they change their places of attachment, thus leaving the previous sites of attachment to become ulcerative. Perforation of the intestinal wall occasionally may occur. The parasite makes the intestines worthless for sausage casings. White grubs, the larvae of May and June beetles, serve as its intermediate hosts. White grubs are found abundantly just below the surface of the soil, particularly in grasslands, and are relished by hogs, which uncover them as they root up the ground.

The eggs of the thorny-headed worm, which are expelled in the feces of the swine, hatch when they are ingested by the white grubs. In the grubs, the larvae hatching from the eggs are released in the midgut; then they migrate to the body cavity and there develop into the infective stage within 2 to 3 months in summer. Since the infective larvae persist when the pupal and beetle stages of the insect develop, pigs become infected by ingesting infected grubs, pupae, or adults.

The larvae of the dog and cat fleas are vectors of the double-pored tapeworm, *Dipylidium caninum*. Because

the adult flea has sucking mouth parts, infection in this stage is impossible. Flea larvae ingest the eggs of the tapeworm. In the larva, the tapeworm grows but slightly. It grows more in the pupal stage and transforms into the infective stage in the adult flea. The



White grub.

cysticercoid lies free in the body cavity of the flea. The cat or dog becomes infected by ingesting fleas or lice.

MORE THAN one kind of intermediate host is required in the development of some of the heteroxenous worms. One of them may be an insect—as in the case of the oviduct fluke of poultry, *Prosthogonimus macrorchis*, which utilizes a snail, *Amnicola limosa porata*, as its first intermediate host and dragonflies as its second intermediate hosts. Species of several genera of dragonflies, *Leucorrhinia*, *Tetragoneuria*, *Epicordulia*, and *Mesothemis*, may serve in the capacity of secondary intermediate hosts for this trematode.

In the United States, the oviduct fluke is found naturally in ducks, Canada geese, and chickens, chiefly in the Great Lakes region. Here the snail that is the intermediate host is found in abundance on the under sides of boards and sticks and may be found traveling along the lake bottom in water 1 to 2 feet deep.

The snail becomes infected by ingesting the eggs of the fluke. After going through several stages of development in the snail, the young flukes (cercariae) escape from its body and swim freely about in the water. The free-swimming organisms are drawn into the anal openings of aquatic naiads, or immature dragonflies, with the water that is alternately taken in and

forced out by the organs of respiration located at the posterior end of the alimentary canal. After entrance into the body of the naiad, the young flukes encyst in the muscles and in most instances are found in the ventral portions of the posterior part of the body. Infection of the secondary intermediate host usually takes place during the late spring and early summer, so that the young flukes sometimes remain in the insect host for 1 or 2 years before they are ingested by the definitive host.

Infection of the bird host occurs usually at the end of May or beginning of June, when the dragonfly naiads are transforming into adults. Infection may also occur by the ingestion of infected mature dragonflies, which can be easily captured by birds in the early morning. The immature worms pass posteriorly to the diverticulum of the cloaca or to the cloaca itself, where they develop to maturity. Some of the worms develop to maturity in the oviduct and have been found in eggs laid by infected hens. The presence of this fluke in laying hens may result in a sharp drop in egg production, the laying of soft-shelled eggs, and, in advanced cases, peritonitis.

*Prosthogonimus macrorchis* is probably the most important fluke parasite of poultry in the United States. However, it is localized around certain sections of the Great Lakes region. That is cause for not too great alarm, because the sections are not important poultry centers.

MANY ADULT INSECTS depend on blood for food. Among those that have been reported to be vectors for worms of livestock are mosquitoes, midges, fleas, sucking lice, and ticks. They ingest worm larvae as they feed on the blood or lymph of infested animals. All the worms they transmit are roundworms of the group Filarioidea.

Mosquitoes of the genera *Anopheles*, *Aedes*, and *Culex*, the dog flea, and the cat flea are suitable intermediate hosts of the dog and cat heartworm. This large worm, 5 to 12 inches long, oc-

curs mainly in the right ventricle of the heart and the pulmonary artery of the dog, cat, fox, and wolf. Many studies indicate that it occurs principally in the Southern States. It may occur throughout most of the United States, although not endemically. Hunting dogs are more seriously affected than other breeds. The infected animal tires easily, gasps for breath, and may collapse. Severe complications, such as inflammation of the kidney and urinary bladder, may arise. In severe cases, the animal becomes poor, and the hair and skin are dry. Abnormal heart sounds are infrequently noted, but moist rales are occasionally present.

About 24 to 36 hours after the mosquito or flea has sucked blood of an infected animal, the larvae or microfilariae may be found within the tissue cells of the Malpighian tubules. There they develop to the infective stage within 5 to 10 days, when they migrate to the mouth parts of the intermediate hosts and are ready to be transferred to a final host during the act of biting.

Mosquitoes of the genera *Aedes* and *Anopheles* are vectors for *Dirofilaria repens*, a rather small worm occurring in the subcutaneous tissue of dogs in southern Europe, Asia, and South America. The worms may cause pruritis without skin lesions.

The dog sucking louse, the dog flea, and the brown dog tick have been reported as vectors of *Dipetalonema reconditum*, originally reported from the perirenal tissue of the dog in Europe. The worm also occurs in other organs and tissues, including the vascular system, lungs, and liver. The brown dog tick also transmits *D. grassi*, which occurs in the subcutaneous tissue and body cavity of the dog in Italy.

Twelve days after microfilariae of *Dirofilaria scapiceps*, which lives under the skin in the loins and in the subcutaneous tissues of the fore and hind legs of wild rabbits in the United States, had been ingested by *Aedes* mosquitoes, infective larvae were seen actively moving in the proboscis of the

insects. Microfilariae also were observed in the gut contents of an unidentified engorged tick. Attempts to infect rabbits experimentally with this roundworm by allowing infected mosquitoes to feed on them have failed. The rabbit tick may also be a suitable intermediate host of this worm, although it has not been incriminated.

Species of biting midges, or sand flies, and black flies have been incriminated as intermediate hosts of species of the genus *Onchocerca*. *O. reticulata* occurs in various countries in the large tendon supporting the neck of the horse and mule and has been reported as a possible causative agent of poll evil and fistulous withers. This worm supposedly is transmitted by *Culicoides nubeculosus*. *Simulium ornatum* is the vector of *Onchocerca gutterosa*, which occurs in the neck tendon and other parts of the body of cattle. *Onchocerca gibsoni*, which lives in the subcutaneous connective tissue of cattle, often giving rise on the brisket and the external surfaces of the hind limbs to nodules, in which the worms lie coiled up, is reported to develop in *Culicoides pungens* and also in black flies. The microfilariae, infrequently found in the nodules or worm nests, are more often found in the walls of the blood vessels and along the lymph spaces. Infected animals show no symptoms except the nodular swellings under the skin, but their carcasses are condemned as unsuitable for sale on most markets.

The stable fly is a reported vector for *Setaria cervi*, which occurs free in the body cavity of cattle and various species of antelope and deer. This worm has been found in the eyes of horses and the udder of a cow.

Other reports indicate that in Asia this parasite is transmitted by three species of mosquitoes (*Anopheles hyrcanus sinensis*, *Armigeres obturbans*, and *Aedes togoi*). The last is also a vector for *S. equina* of horses. Larvae of both species are said to invade the central nervous system of horses, causing lumbar paralysis.

Skin lesions due to the presence in

the lesions of both adults and microfilariae of *Stephanofilaria stilesi*, *S. deodoei*, *S. kaeli*, and *S. assamensis* have been reported from the abdomen and legs of cattle in North America, Java, Malay Peninsula, and India, respectively. Presumably insects transmit them.

The invasion of the skin of sheep by the microfilariae of *Elaeophora schneideri*, which lives in its host's carotid and iliac arteries, produces a dermatitis primarily in the back part of the head but tending to spread over the face to the nostrils. Similar lesions are sometimes noted on the hind foot used to scratch the head. The presence of the larvae in the tissues results in intense itching, which causes the animal to scratch itself. The scratching causes destruction of tissue. The condition has been confined to summer mountain ranges in New Mexico, Arizona, Colorado, and possibly Utah. The life history is unknown, but it is suspected that bloodsucking insects serve as intermediate hosts of the parasite.

IN THE SOLUTION of the problem of the control of insect-borne worm infections of livestock and poultry, six general avenues of approach are available: The use of drugs therapeutically; the use of drugs prophylactically; physical and chemical sterilization of stable and poultry manure and sanitary disposal of excrements; elimination of the breeding places of insects; destruction of insects and their larvae chemically and mechanically; and mechanical prevention of the access of insects to farm animals.

Although the primary purpose of therapeutic treatments directed against the worm infections is to improve the health and efficiency of the sick animal, they have some value in control. After treatment, which eliminates worms from the animal's body or kills them in the body, there is, until reinfection occurs, a reduction in the number of eggs or larvae voided by the animal or the number of larvae entering its tissues. Drugs may be used prophy-

lactically to combat certain of the insect-borne worm infections. Hetrazan administered orally to persons having filariasis causes a rapid and marked reduction in the number of microfilariae in the blood even though the adult worms are not killed. Fouadin, one of the standard drugs in the treatment of heartworm infections in dogs, has a similar effect when injected into these animals. It also inhibits the reproductive capacity of the adult female worms. It is likely that other drugs may be found to operate similarly against the microfilariae of other worms of domesticated animals.

When the economic value of the animal to be protected warrants, stable manure or poultry manure may be promptly collected and stored so as to exclude flies and perhaps other insects from it. Horse manure may be stored in piles so that some of the worm eggs and larvae in it will be destroyed by the heat of its decomposition. This effect may be heightened by storing it and cow manure in covered insulated wooden manure boxes. Evidently it has not been determined specifically that the eggs and larvae of heteroxenous worms are killed by these procedures; however, in all cases investigated it has been found that the eggs and larvae of worm parasites generally are killed by approximately the same degree of heat (about 140° F.).

Several chemical agents will kill the eggs and larvae of monoxenous worm parasites in stable manure. None, to our knowledge, has been specifically demonstrated to be effective against the eggs and larvae of the heteroxenous worms. Some of the agents do kill ascarid eggs, which are thick-shelled, and the means for killing chemically all types of worm eggs and larvae in manure probably are at hand. Investigation to prove this is needed, however. Stable or poultry manure which has not been processed in some manner ought not be used on the farm for fertilizer.

The destruction of breeding places and direct attacks against insects and

their larvae are weapons that can be applied generally to control these vectors. Usually both lines of attack should be employed, but the habits and life histories of insects are so diverse that the weapon of choice—habitat destruction or larvicide or destruction of the adult—may differ with the insect to be fought.

Attacks against the house fly can be directed most feasibly and easily against the larvae. DDT has been reported to be effective against the maggots of this fly when used in a water emulsion. Such an emulsion was found to be effective also against certain other species of flies breeding in poultry manure. DDT, methoxychlor, chlordane, lindane, and other insecticides are recommended as residual sprays directed toward the control of the adults. Important supplemental measures include disposal of manure, chemical treatment of manure, the use of properly baited fly traps, and the use of pyrethrum fly sprays.

The stable fly likewise is most vulnerable to attack in its larval stage. A principal measure for its control—applicable also in the case of the house fly—is the destruction of its breeding places. When it is impossible to locate and eliminate all of these, insecticides as recommended for controlling the housefly are distinctly useful against the adult stable flies.

Mosquitoes, biting midges, and black flies breed in water, and the elimination of their breeding places is not always feasible or desirable. Ponds, small pools, and useless swampy areas may often be filled in or drained. Since the maintenance of large ponds and streams is desirable, treating the water with oils to kill the larvae mechanically and with such larvicides as paris green long has been one of the approaches to the problem of mosquito control. DDT when incorporated into an oily vehicle for application to the water surface is effective for the destruction of the mosquito larvae. This insecticide also is of value in killing the adults of mosquitoes, biting

midges, and black flies. Tests have indicated that the larvae of black flies are susceptible to DDT, TDE, and other new chlorinated insecticides.

Cat and dog fleas in and around buildings may be controlled effectively by the use of DDT sprays or dusts. One to two gallons of 5 percent DDT in oil sprayed lightly over areas of 1,000 to 2,000 square feet has been found effective in the complete eradication of adult fleas. Five percent DDT powder, applied with a dust can, is recommended for the destruction of fleas on dogs. The application of the dust to the building will destroy the larvae and adults as they emerge.

Methods are available for the control of grasshoppers, earwigs, and cockroaches. Beetles frequenting poultry manure likewise may be controlled chemically. The use of insecticides against these beetles probably would not be practical in seeking to control worms in poultry flocks having access to large areas, but the confinement of birds, as presently widely practiced, favors the feasibility of measures for beetle destruction in accumulated manure.

In theory, beetles frequenting manure on pastures no doubt also may be dealt with by means of insecticidal dusts or sprays, but we know of no work demonstrating that this is practical. Since it has been demonstrated that the feeding of small amounts of drugs, such as phenothiazine, to cattle prevents the development of horn flies in their dung, it would seem advisable to investigate the possibility that beetles might be controlled as worm vectors by the routine incorporation of suitable insecticidal materials into the diet of farm animals and birds. Manure deposits on pastures may be broken up and spread to reduce the attractiveness of the manure to insects. The maximum adverse effects of dryness and sunlight on worm eggs and larvae may also be had by this step. The chemical destruction of beetle mites on pastures and grazing land apparently has not been investigated, but even were it pos-

sible, its practicability seems doubtful. It seems probable that other means will have to be sought for the prevention of tapeworm infections transmitted by these mites.

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## Insects and the Plant Viruses

L. D. Christenson, Floyd F. Smith

The Russian scientist D. Iwanowski demonstrated in 1892 that sap from tobacco plants with a mosaic disease is infectious after passing through a bacteria-proof filter. It was the first discovery of an amazing group of agents that cannot be seen with ordinary microscopes and that now are called viruses. Many of our most serious and difficult plant-disease problems have been shown to be the results of infections of plants by these minute entities, which are smaller than bacteria. A few of the many different kinds of viruses are even smaller than the largest molecules known to chemists.

Tulip mosaic, peach yellows, aster yellows, sugar-beet curly top, phloem necrosis of elm, tobacco mosaic, raspberry mosaic, blueberry stunt disease, potato leaf roll, pea mosaic, tomato spotted wilt, and sugarcane mosaic are examples of plant diseases caused by viruses. Virus agents also cause serious diseases of man and animals—smallpox, measles, mumps, the common cold, rabies, distemper, and foot-and-mouth disease. Others, like the sacbrood virus of honey bees, infect invertebrate animals.

For a long time we knew little about the nature of viruses. Now, as a result of the studies of W. M. Stanley, F. C. Bawden, N. W. Pirie, and others, they are believed to consist of complex nucleoproteins that have some of the attributes of living organisms. Like living organisms, the individual virus particles can reproduce or multiply. They also can change or mutate during the multiplication process. They do not seem able to grow or multiply, however, except within the living cells of their hosts, and, unlike living or-